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DOI: <https://doi.org/10.1080/23311983.2015.1123080>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-125334>

Journal Article

Published Version



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Originally published at:

Robinson, Brian; Vasko, Stephanie E; Gonnerman, Chad; Christen, Markus; O'Rourke, Michael (2016). Human values and the value of humanities in interdisciplinary research. *Cogent Arts Humanities*, 3:1123080.

DOI: <https://doi.org/10.1080/23311983.2015.1123080>



Received: 02 October 2015
Accepted: 14 November 2015

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Peter Stanley Fosl, Transylvania
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PHILOSOPHY & RELIGION | RESEARCH ARTICLE

Human values and the value of humanities in interdisciplinary research

Brian Robinson^{1*}, Stephanie E. Vasko¹, Chad Gonnerman², Markus Christen³ and Michael O'Rourke¹

Abstract: Research integrating the perspectives of different disciplines, or *interdisciplinary* research, has become increasingly common in academia and is considered important for its ability to address complex questions and problems. This mode of research aims to leverage differences among disciplines in generating a more complex understanding of the research landscape. To interact successfully with other disciplines, researchers must appreciate their differences, and this requires recognizing how the research landscape looks from the perspective of other disciplines. One central aspect of these disciplinary perspectives involves values, and more specifically, the roles that values do, may, and should play in research practice. It is reasonable to think that disciplines differ in part because of the different views that their practitioners have on these roles. This paper represents a step in the direction of evaluating this thought. Operating at the level of academic branches, which comprise relevantly similar disciplines (e.g. social and behavioral sciences), this paper uses quantitative techniques to investigate whether academic branches differ in terms of views on the impact of values on research. Somewhat surprisingly, we find very little relation between differences in these views and differences in academic branch. We discuss these findings from a philosophical perspective to conclude the paper.

ABOUT THE AUTHORS

The authors constitute an interdisciplinary group of researchers, most of whom work on the Toolbox Project (<http://toolbox-project.org>), a research initiative funded by the National Science Foundation and based at Michigan State University. This project is dedicated to facilitating communication and collaboration in team-based research activities at both the national and international levels. The Toolbox Project has conducted over 160 dialogue-based workshops designed to improve the collaborative capacity of interdisciplinary research teams. The Toolbox Project has published over a dozen articles detailing their methods and findings. This article represents the beginning of the Project's research efforts on examining whether academic branches differ in how they think about the role and impact of values on research.

PUBLIC INTEREST STATEMENT

Interdisciplinary science has a reputation for difficulty based on purported clashes between disciplines. But what if this assumption is false? We note that different disciplines represent different intellectual cultures, and the gaps between these cultures can be challenging to bridge. This article is an interdisciplinary effort, based in the humanities, that evaluates the gap between intellectual cultures. Specifically, it evaluates whether researchers possess academic branch-based differences (e.g. social science, physical science, and engineering) on the role of epistemic values in scientific research through a systematic study of data drawn from work by the Toolbox Project. The Toolbox Project utilizes philosophical concepts in dialogue-based workshops to enhance communication in collaborative, interdisciplinary research. Surprisingly, we find little evidence of consistent patterns across these branches. We conclude by arguing that humanists can make a number of important contributions to scientific collaborations that increase the intellectual merit of scientific projects.

Subjects: Epistemology; Ethics Philosophy; Philosophy; Philosophy of Science

Keywords: interdisciplinary scientific research; humanities; values; philosophy; Toolbox Project; “two cultures” gap; interdisciplinary humanities

1. Introduction

More than 55 years ago, C.P. Snow described the regrettable gap that existed between scientific culture and the culture of the humanities and the arts. It would be much better for all of us, he argued, if there could be meaningful interaction between these two cultures (Snow, 1959). To a first approximation, scientists make judgments based on data: they employ empirical methods designed to transform data into evidence that bears on hypotheses about how things stand with the actual world. Humanists, by contrast, rely on narrative and conceptual methods to understand and enrich the human condition. By highlighting the clarifying power of the individual moment and the transformational influence of imagining the possible, the humanities leverage empathic identification in exploring what is it to be a human being in a vast universe. Whether or not you believe that the gap remains as wide as ever,¹ it certainly remains true that it is worth working to bridge the gap between the sciences and arts and humanities in order to bring the different cultures into productive convergence.²

This is an article about the productive convergence of humanities with science. It is an interdisciplinary effort based in the humanities that closes the culture gap along two dimensions, namely, the *collaboration* dimension (i.e. *who* is involved) and the *content* dimension (i.e. *what* is involved). Along the collaboration dimension, our primary emphasis is the work of the Toolbox Project (<http://toolbox-project.org/>), a US National Science Foundation-funded humanities initiative that exemplifies a commitment to bridging the gap between the academic cultures by employing humanistic insights to enhance scientific processes. Specifically, the Toolbox Project utilizes philosophical concepts and methods in dialogue-based workshops to enhance communication in collaborative inter-, cross-, and transdisciplinary sciences (Eigenbrode et al., 2007; O'Rourke & Crowley, 2013). In addition, it is important to note that as a team with training in philosophy, neuroinformatics, and the physical sciences, the authors have combined research perspectives in a reflexive way designed to minimize the potential for prodigious cultural “incomprehension” (Snow, 1959, p. 12).

Along the content dimension, we develop an instance of productive convergence that involves the complex role of values in scientific practice. By “values” in this context, we mean “scientific values” or “good-making” features such as fairness, objectivity, and democratic participation that function (or ought to function) as constraints on reasoning and action in the context of scientific research. Held by both the scientific community and by individual scientists, values help underwrite important theoretical principles of knowledge production—what we will call “epistemic values”—as well as non-epistemic principles of conduct. Given that these good-making features are the subject of humanistic investigation in philosophy, literature, history, and elsewhere *and* that they figure importantly into the practice of scientific research, they can serve as a ground for collaborative interaction between the humanities and the sciences. Further, we adopt a methodological posture that combines a philosophical perspective on values in science with quantitative data analysis techniques drawn from the sciences. In particular, using data generated in dialogue-driven workshops about the philosophical dimensions of scientific practice, we use quantitative techniques to examine whether there are any interesting differences in attitudes and commitments toward values in science across academic branches represented in interdisciplinary research projects.³ Thus, the content of our story exhibits the convergence of the humanities and the sciences, both in terms of what it is about and how we tell it.

We begin our interdisciplinary story in the next section with more detailed descriptions of the collaboration and content dimensions of our effort to bridge the culture gap, focusing specifically on the Toolbox Project and on values in science. It is there that we provide context for the specific research question that guides our analysis, viz., *are there predictable differences in attitude about*

values that are correlated with differences in academic branch? After describing our methods, we discuss the results of our analysis. We conclude with a discussion section in which we highlight a few implications of our data and analysis for efforts to bridge the culture gap.

2. Collaboration and content

In this section, we provide additional details about the two principal dimensions of this project, collaboration and content. First, we describe the Toolbox Project, an effort that functions as a collaborative confluence of humanistic and scientific thinking. We address both the motivation behind the project and the character of its response. Second, we discuss values in science, the topic that constitutes the content of our analysis.

2.1. The collaboration dimension: the Toolbox Project

Collaborative interdisciplinary research essentially involves bringing different disciplinary perspectives into contact with each other, often in the service of addressing complex problems that extend beyond the ambit of any one discipline. These perspectives figure into the constitution of disciplinary *cultures*, which comprise the social, material, and epistemic conditions on our experience, framing both perception and interpretation (cf. Galison, 2006). Cultures can make certain ways of seeing and knowing “natural,” which can make alternative perspectives appear foreign and even incomprehensible (Crowley, Eigenbrode, O’Rourke, & Wulfhorst, 2010). One way to think of this phenomenon in the research context is in terms of “academic tribalism,” or the notion that academics in the same discipline are “united by customs, tradition, and adherence to a largely common worldview” (Sternberg, 2014). Among the problems that are created by academic tribalism, Sternberg (2014) lists “uniformity of point of view” and “rejection of interdisciplinarity,” both of which undermine meaningful interdisciplinary integration (O’Rourke, Crowley, & Gonnerman, *in press*). In talking about these problems, Miller et al. (2008) discuss researchers who operate within “epistemological silos” adhere to disciplinary boundaries and seek “... to acquire and validate knowledge” from their own epistemological perspective. This siloing can lead to the inability of researchers to shift their disciplinary perspectives, or their general way of looking at or thinking about research space, conditioned by tacit assumptions and commitments instilled or reinforced by their disciplinary experiences (Eigenbrode et al., 2007).

Humanistic thinking, and in particular the history and philosophy of science, has helped diagnose problems associated with academic tribalism, and this type of thinking can also help remediate them. One of the central humanistic insights about these problems, emphasized, for example, by feminist epistemologists and philosophers of science (e.g. Harding, 1993) is that greater awareness of hard-to-access disciplinary assumptions and commitments can be promoted through interactions with individuals who do not share those assumptions and commitments. Such an individual can function as a “stranger” (Simmel, 1921) or an “outsider within” (Collins, 1986; Merton, 1972), who is better able to spot theoretical features that emerge from unquestioned assumptions and commitments, especially when the assumptions or commitments are not shared. In a interdisciplinary collaboration, each project member can play the role of the “outsider within” for other members by virtue of their different worldviews, perspectives, experiences, etc; thus, so long as differences in worldview are harnessed in a way that illuminates potentially divisive variations in perspective, the source of the malady can also be the source of its cure.

The Toolbox Project is motivated by the goal of facilitating the identification of these differences in worldview so that interdisciplinary collaborations can mine them, rather than be undermined by them. Heightened collective reflexivity about these differences can put collaborators in a position to appreciate the potential for confusion and disagreement (Gonnerman, O’Rourke, Crowley, & Hall, 2015), enabling members of the project team to see the research landscape through each other’s eyes (Looney et al., 2013). The principal vehicle for facilitating this appreciation is a two- to three-hour Toolbox workshop that centers on a semi-structured philosophical dialogue among collaborators (O’Rourke & Crowley, 2013). Contributions to these dialogues are prompted by a survey instrument—the “Toolbox”—designed to reveal the tacit assumptions and commitments that

condition various aspects of disciplinary research practice. Typically, Toolbox instruments are designed to suit a particular collaboration, highlighting the assumptions and commitments that are operative in its particular context. The dialogues these instruments structure often include revelation of surprising difference, negotiation of conflicting perspectives, and an increase in mutual understanding (Schnapp, Rotschy, Hall, Crowley, & O'Rourke, 2012).

A Toolbox survey instrument comprises a number of prompts that articulate or closely connect up with positions on issues that frame scientific research, such as “Scientific research must be hypothesis driven” and “Scientific research aims to identify facts about a world independent of the investigators.” These prompts are selected because they get at different ways of understanding research, including its objects and uses, e.g. whether one regards hypothesis formation and testing as key to an adequate research design, or whether scientific researchers are inevitably implicated in their own research findings. The instrument asks participants to rate their agreement with these prompts on a five-point Likert scale (1 “Disagree” to 5 “Agree,” along with “I don’t know” and “N/A”). The prompts are organized into modules, or sets that center on a specific philosophical theme articulated in the form of a core question. For example, the Science–Technology–Engineering–Mathematics (STEM) instrument, which is the instrument of concern in this article, consists of six modules that concern fundamental aspects of the epistemology and metaphysics of science, including Methodology, Confirmation, and Values (Looney et al., 2013). Our focus is the Values module contained in the STEM instrument, which is built around the core question, “Do values negatively influence scientific research?” The prompts contained in the Values module are described below.

2.2. The content dimension: values in science

For more than 60 years, philosophers of science have put forward a wide variety of positions on the relationship between non-epistemic values and scientific research. As we suggested above, non-epistemic values comprise good-making features of individuals and societies (e.g. justice) that differ from the good-making, theoretical features of scientific knowledge production, especially insofar as truth is concerned (i.e. *epistemic* values, such as explanatory scope or objectivity). To a large extent, the Toolbox Values module emerges out of a close study of this literature. What follows are the five main prompts in the module, along with the philosophical positions that helped inspire them.

- (1) “Objectivity implies an absence of values by the researcher.” Longino (1990, 2002) argues that scientific objectivity does not require that individual scientists be value-neutral; instead, objectivity emerges from community criticism.
- (2) “Incorporating one’s personal perspective in framing a research question is never valid.” Harding (1986, 1987) defends the claim that value orientations, such as those related to gender, may legitimately influence the framing of research questions in science.
- (3) “Value-neutral scientific research is possible.” Defenders of the value-free ideal (e.g. Poincaré, 1958, p. 12)—i.e. the idea that science should aim to be free of the influence of non-epistemic values—would contend that in some facets of science, such as when deciding whether to accept a hypothesis in light of the available evidence, the influence of non-epistemic values should be minimized (cf. Lacey, 1999).
- (4) “Determining what constitutes acceptable validation of research data is a value issue.” Rudner (1953) and Douglas (2000) argue that non-epistemic values may influence decisions about whether the available evidence is sufficient for accepting a scientific claim, as when the consequences of accepting the claim would be intolerably bad were the claim to turn out false, despite the available evidence.
- (5) “Allowing values to influence scientific research is advocacy.” Kourany (2003) defends the claim that scientists have a responsibility to advocate for socially significant goals about which they have expertise, such as public health. ⁴

As we noted above, the literature on interdisciplinarity commonly regards differences between disciplines as a great obstacle to effective interdisciplinary team collaboration (e.g. Benda et al.,

2002; Eigenbrode et al., 2007; Miller et al., 2008). As Lélé and Norgaard (2005) observe, these differences include epistemic value differences that arise out of diverse types of training and ways of conducting research (e.g. different choices of “variables and models,” p. 975). These epistemic differences are an integral part of disciplinary culture, a point made by Becher and Trowler, who write, “in practice, academic cultures and disciplinary epistemology are inseparably entwined ... disciplinary knowledge forms are to a large extent constituted and instantiated socially” (2011, p. 23). But non-epistemic values are also implicated in interdisciplinary work. Fisher et al. make an observation about non-epistemic values, noting that “divergences between human value dimensions and technical rationalities” constitute a “socio-technical divide” that is often manifest in collaborative interdisciplinary projects that focus on socially relevant problems (2015, p. 3).

These observations suggest that we should expect some disciplinary pattern to emerge in participant responses to the five Toolbox Values prompts, and this suggestion is the source of our initial research question: *Are there predictable differences in attitude about values that are correlated with differences in academic branch?* As we will discuss below, we opt to evaluate academic branches rather than disciplines under pressure from our data-set, but the interest remains the same: Are perspectives on values in science as articulated in the five prompts among the differences that divide different domains of science?

3. Methods

To investigate variance in attitudes toward values across academic branches, we examined Likert responses from participants in 43 workshops conducted by the Toolbox Project between March 2009 and October 2013. Since 2005, more than 160 Toolbox workshops have been conducted with over 1,400 participants. Of these workshops, these 43 workshops were selected for our sample because (a) they were conducted with cross-disciplinary research teams collaborating on a joint project and (b) they used the STEM Toolbox instrument. These workshops had 355 participants (127 female), ranging from graduate students to senior researchers with over 20 years of research experience. Of the 43 workshops, all of them had multiple disciplines represented, and all but one had multiple academic branches represented.

A Toolbox workshop begins with participants completing a Toolbox instrument, which includes a demographic table along with the Likert items described above. Among the demographic variables is disciplinary identity, specifically, which discipline(s) constitute a participant’s “primary identity.” Participants provided up to four open-ended disciplinary specifications in numbered spaces. As there were no constraints on these specifications, it was often unclear in our sample just how closely aligned participants were in terms of their disciplinary identity. To normalize disciplinary specification, we coded responses using a comprehensive and systematic discipline taxonomy. We focused on the item listed in the first of the four numbered spaces in each demographic table, which we took to be the most salient disciplinary affiliation for participants who listed more than one, and so the principal disciplinary component of these more complex identities. Two co-authors categorized these disciplinary specifications using the Digital Commons Three-Tiered Taxonomy of Academic Disciplines (Bepress, 2014).⁵ The raters independently associated the first item listed with a discipline in the taxonomy, noting the academic branch under which that discipline is classified. For instance, the discipline Philosophy falls under the academic branch Arts and Humanities; Bioinformatics is under Life Sciences; and Earth Sciences is under Physical Sciences and Mathematics. Each participant was thus associated with both a primary discipline and academic branch for the purposes of subsequent analysis.

Given that the number of disciplines is high, with over 330 disciplines included in Bepress, 2014, we were not able to populate the disciplinary categories from our sample in sufficient numbers to justify analysis at the disciplinary level. This problem was resolved, however, by shifting the evaluation to the level of the academic branch (Table 1). Therefore, our analysis examines whether there are differences among academic branches. This method assumes that any differences between two disciplines in the same academic branch will be minor compared to differences between any two

Table 1. Summary of participants' academic families as determined by two raters

Academic braches	Total participants
Life Sciences	134
Physical Sciences and Mathematics	72
Social and Behavioral Sciences	58
Engineering	34
Medicine and Health Sciences	17
Arts and Humanities	8
Education	10
Business	2

Notes: The Digital Commons Three-Tiered Taxonomy of Academic Disciplines has 10 academic branches, of which we had participants from 8. Missing from our list are the branches Law and Architecture, from which we had no participants.

academic branches. For instance, Economics and Political Science, both members of Social and Behavioral Sciences, likely differ in their research worldviews or in their philosophical assumptions and commitments regarding the practice of science, but we assume that these differences tend to be minor by comparison with the differences that obtained between Social and Behavioral Sciences and the Physical Sciences and Mathematics branch. Although much of the literature on the integrative challenges to interdisciplinary research describes these challenges in terms of disciplines, we argue that it is legitimate to pursue our research question at this level because of the taxonomic nature of knowledge organization. As exhibited by the Bepress's (2014) taxonomy, disciplines can be organized by various epistemic and ontological affinities into broader branches that inherit some of the epistemic and ontological characters of their constituent disciplines; for this reason, it is legitimate to expect integrative challenges of the sort that motivate the Toolbox Project to percolate up to the level of the academic branch.

We predicted that some pattern at the level of academic branch will emerge from participants' responses to the five Toolbox Values prompts. Since our inquiry into the distribution of views values in science is exploratory, our prediction remains non-specific. We did not, for example, predict what views on value neutrality are associated with the academic branches. We tested the expectation that there will be differential patterning across academic branches in two ways. First, organizing participants into academic branches, we analyzed participant responses to each Values prompt individually to determine if any statistically significant difference can be found between academic branches. For any prompts showing a significant difference among the academic branches, we used a follow-up analysis to look for where the significant difference lies, i.e. which academic branches are statistically distinguishable by means of that prompt.

Second, we determined the similarity of the answers by transforming the answers of each participant into a vector whose components correspond to the chosen Likert scale values and calculating their pairwise Euclidean (i.e. straight-line) distance.⁶ The resulting distance matrix was used in two different ways for cluster analysis. First, we used a standard algorithm for identifying clusters in the data, a variant of k-means clustering, implemented in Mathematica. Second, we employed a super-paramagnetic agent visualization technique to look for how the Toolbox participants cluster based on their responses to the Values prompts collectively.⁷ This method of analysis produces a map depicting every participant as a dot. The position of each participant on the map is determined in relation to every other participant based on how similar their responses are to each other. Participants with very similar answers are closer together, while those with highly dissimilar answers are quite far apart. For instance, suppose participant A responded 1 ("Disagree") to all the Values prompts, participant B responded 5 ("Agree"), and participant C responded 1 to four of the prompts and 2 to the fifth. In this case, A and C would be mapped closely together and far apart from B. Once all the participants have been plotted, we can look for groups of participants that have clustered together

based on their similar response patterns. The superparamagnetic agent mapping technique analyzes the similarity of participants and maps them independently of their academic branch. We then colored participants on the map according to their academic branches. While the superparamagnetic agent mapping plots participants relative to each other based on the similarity of their responses, it may not be immediately clear from looking at the map how many clusters there are (if any) or what the boundaries of any cluster are. Thus, the *k*-means clustering algorithm was also applied to the resulting SAM map by taking the coordinates of the points on the map as input for calculating the distance matrix. This way, we are not left to subjectively interpret how close two dots look to each other. We then predicted that at least some of the clusters that emerged in either way (*k*-means or SAM) would be based on academic branch.

4. Results

The raters initially excluded nine participants for providing responses that did not correspond to any discipline in the taxonomy, such as “policy” and “grant administration.” For academic branches, the two raters achieved a relatively high degree of correspondence ($\kappa = 0.82$), differing on 54 of the remaining 346 participants. Forty-three of these differences were resolved; the 11 participants about whom disagreement remained were excluded from subsequent analysis. The results are summarized in Table 1.

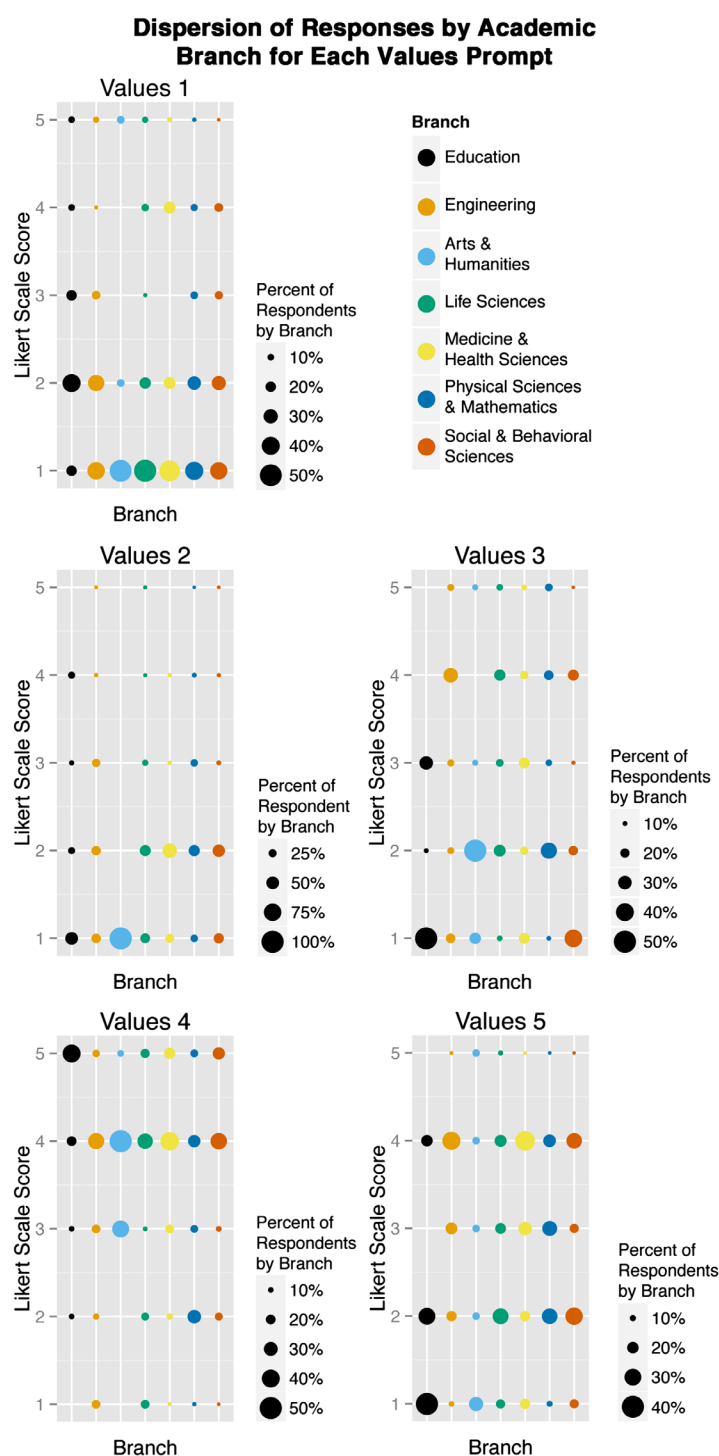
Most heavily represented in our sample were the science branches and engineering; the dearth of representatives in arts and the humanities is worth noting and will be addressed in the Discussion section. Given the unequal distribution of participants across the academic branches, some branches had to be excluded from the statistical analyses of each prompt. For instance, Business was excluded because a sample of two participants is too small to support inferences about Business as a whole from their responses. For the *k*-means clustering analysis and the superparamagnetic agent mapping, however, all participants for whom an academic branch could be ascertained (335) are retained since those analyses only look for similarity between individual participants’ responses, regardless of their academic affiliation.

To visualize the variance in the data, we produced weighted scatterplots of responses by academic branch (Figure 1). Each academic branch is represented on the X-axis, with each of the five Likert responses on the Y-axis. For each branch, we plotted a dot on each of the Likert values that participants of that academic branch gave. In the case of Values 1, for instance, participants from Arts and Humanities only responded 1, 2, or 5, and so dots only appear for those Likert values for this branch. We then made the size of each dot proportional to the percentage of participants giving that response.⁸ The key point worthy of note from this visualization is how widely distributed the responses were. Participants gave a wide range of responses to each prompt. With very few exceptions, each of the possible responses (1–5) was recorded for each prompt and for each academic branch.

Next, we compared the branches to each other to determine if there were any significant differences for each prompt. For this analysis, we used the Kruskal–Wallis *H* test.⁹ This test takes the null hypothesis that for a given prompt, the medians of each academic branch are equal ($Mdn_{Life Sciences} = Mdn_{Physical Sciences \& Mathematics} = Mdn_{Social \& Behavioral Sciences} = Mdn_{Arts \& Humanities} = Mdn_{Medical Sciences} = Mdn_{Engineering} = Mdn_{Education}$). This null hypothesis is rejected if the probability of the data given this null hypothesis is less than 5% ($p < 0.05$). Thus, when the null hypothesis is rejected, it means that there is a statistically significant amount of variance between branches. A series of follow-up analyses are necessary to attempt to determine which branches are statistically distinguishable by the prompt in question. Table 1A in Appendix 1 summarizes the results for the Kruskal–Wallis tests of each prompt, where Business was excluded. There were statically significant differences between academic branches for Values 2, “Incorporating one’s personal perspective in framing a research question is never valid” ($H(6) = 17.81, p = 0.007$) and Values 3, “Value-neutral scientific research is possible” ($H(6) = 18.96, p = 0.004$).¹⁰

Figure 1. Summary of Likert responses by academic branch for each values prompt.

Note: The color-blind friendly color palette for Figures 1 and 2 were adapted from Okabe and Ito (2002).



To tease apart the nature of these results, we conducted a follow-up analysis of Values 2 and Values 3 using the Mann–Whitney–Wilcoxon (MWW) test. For each prompt, this test conducts a series of pairwise comparisons, separately comparing each branch’s median to every other branch’s median. We can then determine which pair(s) of branches are different from one another in a statistically significant manner. In order for the MWW test to return results, academic branches with fewer participants had to be excluded from the analysis. Thus, the follow-up analysis could only include Life Sciences, Physical Sciences and Mathematics, Social and Behavioral Sciences, and

Engineering. The means for each of these four branches and the differences between them are represented in Figure 2. The full results of the MWW tests are summarized in Table 2A in Appendix 1.

The MWW tests found only one pairwise comparison that showed statistically significant difference after decreasing the likelihood of a Type I error (i.e. a false positive).¹¹ Participants in Social and Behavioral Sciences (Mdn = 2) were significantly less likely to agree with Values 3 (that value-neutral scientific research is possible) than were participants in Life Sciences (Mdn = 3) ($W = 4639$, $p = 0.002$). The means of the other three academic branches on this issue are around the mid-point. The differences between Social and Behavioral Sciences and both Engineering ($W = 1210$, $p = 0.03$) and also Physical Sciences and Mathematics ($W = 2586.5$, $p = 0.006$) were nearly significant. No pairwise comparisons were significant for Values 2, though the difference between Social and Behavioral Sciences and Physical Sciences and Mathematics was nearly significant ($W = 2432.5$, $p = 0.03$). It is possible that the significant result for Values 2 from the Kruskal–Wallis H test was due to a difference involving one of the academic branches that had to be excluded from the MWW tests.

The analysis presented so far looked for differences between academic branches relative to individual prompts. All these prompts belong to the Values module and were all originally designed to motivate discussion of issues related to the module’s core question, “Do values negatively influence scientific research?” (Eigenbrode et al., 2007). A reasonable question, then, is whether there is any branch-based pattern in participant responses across all five Values prompts? For example: Do participants belonging to the Social and Behavioral Sciences branch tend to respond in roughly the same way to all five prompts, and if so, are they distinct from all other academic branches or participants from other branches also respond in a similar fashion? To answer these questions, we use the k -means clustering algorithm and the superparamagnetic agent mapping technique explained in Section 3 to look for clusters of similar response patterns among our participants across all five Values prompts.¹² We indeed found 17 clusters using k -means clustering, but they did not correspond to the academic branches.¹³ Also, the resulting SAM map (not shown) did not display any clustering along disciplines.

One possible explanation of the lack of clusters corresponding to academic branches is that some of the prompts were too noisy, i.e. they were not accurately capturing differences between branches.

Figure 2. Summary of means for the Values 2 and 3 prompts by academic branch. Error bars indicate ± 1 standard deviation.

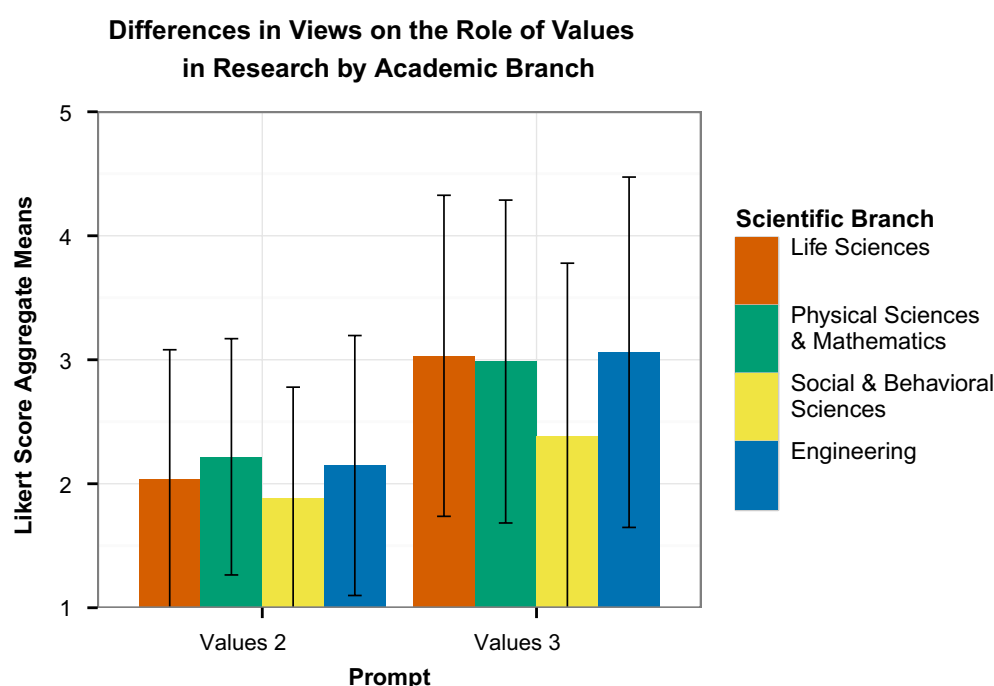
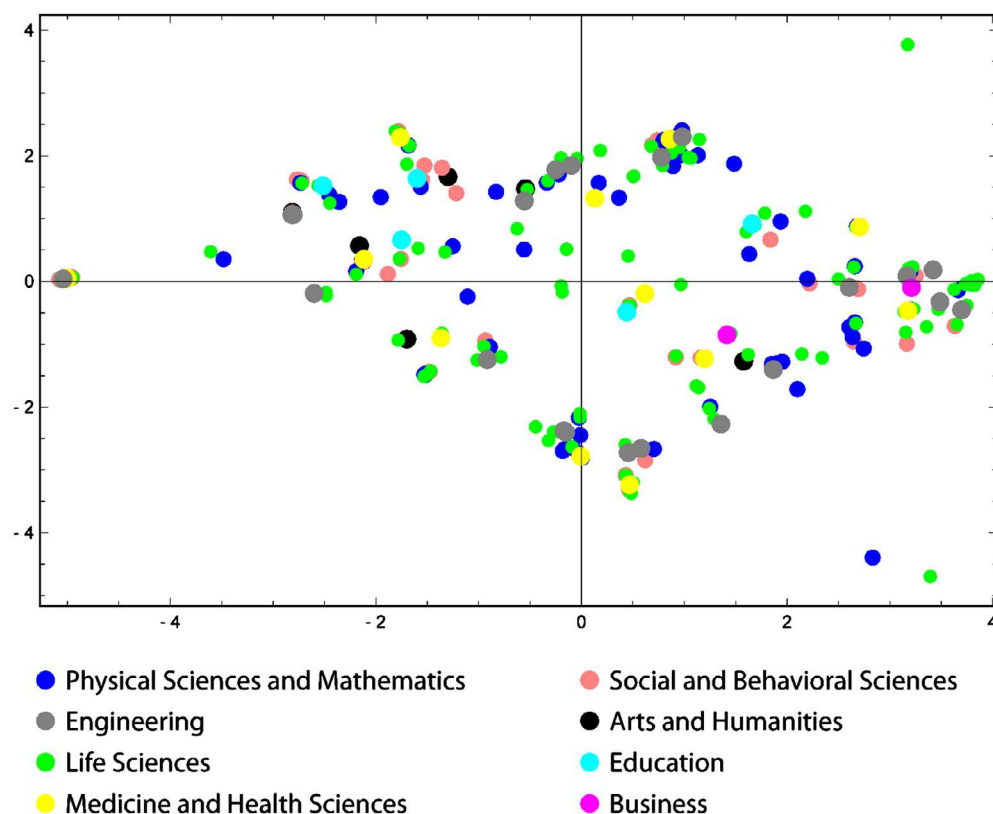


Figure 3 Results of superparamagnetic agent mapping for participant responses to Values 2 to 4 and color coded by academic branch.



The Kruskal–Wallis H tests revealed precisely this result. Both Values 1 ($H(6) = 4.22, p = 0.65$) and Values 5 ($H(6) = 6.81, p = 0.38$) were far from statistically significant, giving us some reason to think that academic disciplines do not explain variances in responses to these prompts. We suspected that we would find the predicted clustering by academic branch when using only the answers for Values 2 to 4 for calculating the distance matrix. However, the result was negative again. Although k -means clustering found eight clusters, they were completely unspecific regarding academic branches. The same holds for SAM mapping as Figure 3 shows. We remind the reader that each dot represents a participant, color-coded based on academic branch. If there were a correspondence between identified clusters and academic branches, most of the dots of the same color would have been clustered together or at least located in the same region of the plane, instead of being spread all over the map as seen here.

We take this result to be somewhat surprising since it indicates that interdisciplinary researchers' views on the issues raised in Values 2 to 4 do *not* conform to any pattern based on academic branches. Rather, researchers are scattered about the map, showing a wide diversity of views across academic branches. Though we set out to find difference among academic branches, we found very little by examining the prompts individually or collectively. We consider below how to interpret these null results.

5. Discussion of results

At the outset, we predicted that clear differences would emerge based on the academic branch to which participants belong. Contrary to our prediction, we largely did not find the expected branch-level divides. The only difference we did find was that social and behavioral scientists were significantly less willing to agree that value-neutral scientific research is possible than were life scientists. This result is not too surprising since researchers in the Social and Behavioral Sciences will have been influenced by post-positivism and its embrace of values as a key part of the scientific process (cf.

Lélé & Norgaard, 2005). Even more interesting than the lack of branch-level divides was the lack of any clustering of researchers according to academic branch.

If we only considered the statistical tests that examined prompts individually, it would be hard to make much of these results. Not finding significant differences doesn't confirm the null hypotheses that there are none. The lack of branch-based clustering produced by superparamagnetic agent mapping is a different story, however. Rather than testing a null hypothesis to see if it should be rejected, it produces a map that groups the participants based on similarities in their answers. Therefore, the lack of clustering based on branches is an interpretable result, whereas that is not in general true of the failure to reject a null hypothesis. Furthermore, the fact that both methods did not find branch-based differences represents convergent evidence that there are no such differences here. The combination of the lack of clustering according to branches and the failure to find statistically significant differences suggests a few conclusions. First, recall that our data show that researchers supplied a wide diversity of responses to our prompts on values in science (see Figure 1). This indicates that the lack of clustering is *not* due to researchers generally having the same views, regardless of academic branch; rather, our findings suggest that interdisciplinary researchers have a diversity of views about value-neutral inquiry and that this diversity is not based on the academic branch to which a researcher belongs. Second, while the differences may be individual or based on some other demographic factor, they do not seem to be based on academic branch. Third, if this tentative conclusion is correct, and further investigation is warranted, then it suggests that some differences one might expect to be revealed and managed by the careful negotiation of differences in research worldview may in fact be left unaddressed. Some important differences (like whether value-neutral scientific inquiry is possible) that could be obstacles for successful collaboration might transcend research domains.

Of course, our analysis has focused on differences at the academic branch level, leaving open the question of whether there are statistically significant differences in attitudes toward values at the disciplinary level. That we might still expect differences at this level, in spite of the results we report in this paper, is motivated by the idea of academic tribalism/siloing, which suggests that it is reasonable to expect disciplines to differ in various ways as a result of differences in "customs, tradition, and adherence to a largely common worldview" (Sternberg, 2014). While we have emphasized that analysis at the level of individual disciplines would be ideal, this remains a step for future research. One way to determine if there is a tribalism/siloing effect across disciplines is to gain greater representation from disciplines in Medicine and Health Sciences, Arts and Humanities, Education, and Business, either in focused surveys on questions raised here or in future Toolbox sessions. We can also explore the question using qualitative methods, such as textual analysis of Toolbox dialogues and participant interviews focused on formation of disciplinary identity and the development of values that influence research. If attitudes toward prompts such as "Value-neutral scientific research is possible" are socially constructed in the disciplines, then we should observe this through interviews and exploration of the data at discipline granularity.

One important fact about our sample that we have not addressed is the paucity of humanists engaged in interdisciplinary collaboration with the sciences. The Toolbox Project has collaborated with a large number of scientific research projects that represent a broad spectrum of interests and are funded by a variety of agencies, including NSF, NIH, and USDA-NIFA. If a sizeable percentage of these collaborations involved humanists as members, that would be a salutary sign that the culture gap is closing; however, of the 346 participants included in our sample, only 8 self-identified as belonging to the Arts and Humanities as their primary disciplinary identity. One might take this to mean that humanists have little to contribute, but this would be a mistake. Rather, it means that few in the sciences are aware of what a humanist can contribute, and further, few in the humanities are aware of it either. Following Snow, we submit that the lack of interdisciplinary interaction involving scientists and humanists is less about hostility and more about mutual ignorance. As Snow put it, "They have a curious distorted image of each other" (p. 4).

Our data-set, then, evinces the an important culture gap. The Arts and Humanities appears to remain largely excluded from interdisciplinary research with the sciences. While our study does not offer evidence about the etiology or extent of the gap, it does suggest that it remains in place. Although we are not in a position to comment on *causes*—on why, based on our sample, there are so few humanists—we are in a position to argue for the value and relevance of humanities scholarship to interdisciplinary science. More should be done to impress on scientists and humanists alike that there would be mutual value in collaborating, and in particular, collaborating on funded scientific projects.¹⁴

It is important to emphasize that this mutual value is not incidental but is in fact central to the mission of the sciences. Embedding scientific results in the arts and humanities—e.g. arts projects, writing projects, and historical inquiry—is one way to connect the humanities with complex, interdisciplinary science projects (Goralnik, Nelson, Ryan, & Gosnell, 2015); however, applying science in humanistic contexts tends to be regarded as inessential and peripheral by those engaged in the scientific work. These count as *broader impacts* of the science, rather than essential moves made as part of a project's *intellectual merit* (http://www.nsf.gov/bfa/dias/policy/merit_review/; for discussion, see Holbrook, 2005). We are interested in bridging the humanities with the sciences in a way that demonstrates how the humanities can be relevant to the *intellectual merit* of these projects.

Humanists are not typically trained to address the technical aspects of scientific data collection and analysis (though philosophers of science are increasingly an exception to this trend), but they are trained to evaluate the humanistic aspects of scientific practice, which leaves much to do in a typical scientific project. We conclude our discussion with brief descriptions of three specific contributions that humanities can make to the intellectual merit of a collaborative interdisciplinary project. (This list is meant to be illustrative and not exhaustive.)

- (1) *Serve as vectors of clarity and criticism about values.* As we have noted, values that figure into science can be epistemic or non-epistemic. An important type of non-epistemic value is *ethical* values, and humanists are in an especially strong position to contribute to science projects by clarifying these values. This is evident in the work that philosophers do on responsible conduct of research and the role they play in larger projects as contributors to an understanding of ethics in science. NSF and NIH recognize this by highlighting ethics as a key part of scientific and biomedical projects. There is also reason to see ethical values as standing in important, “coupled” relationships with epistemic values, establishing interrelated assemblies of value in the context of science (Tuana, 2010). Given this more complex picture, Tuana (2013) argues that in addition to clarifying ethical issues of accountability and responsibility, “rendering ... values transparent and examining their coupled ethical-epistemic significance is an important and often under-appreciated resource for more objective science” (p. 1957).
- (2) *Encourage reflexivity on the part of collaborators concerning their role(s) as scientists and human beings.* It is valuable for scientists to recognize that they bring to scientific work a whole host of assumptions and commitments. The tricky thing about disciplinary assumptions and commitments is that they are often quite hard to spot by those within the discipline, operating something like the bottom part of an iceberg, shaping what is visible above the waters but remaining well below what is directly visible. As we suggested above, the Toolbox Project aims to encourage reflexivity by structuring dialogue among collaborators in cross-disciplinary projects who have different assumptions and commitments, which can reveal potential obstacles to efficient and effective cross-disciplinary practice (Gonnerman et al., 2015).
- (3) *Support the accountability of complex projects to each other and to non-research stakeholders.* The narrative of a complex science project matters—it is, for example, a critical part of accounting for the value of science and communicating that value, to other scientists, to funding agencies, and to non-scientists (Huutoniemi, 2015). Humanists have the ability to aid in the communication and dissemination of projects, and in so doing, frame the reception and

interpretation of scientific results. This is key as projects become more transdisciplinary and participatory (Hall & O'Rourke, 2014).

6. Conclusion

This work described in this paper reflects humanistic thinking and represents two different ways in which the culture gap can be bridged. First, the data on which the results reported above are based come from the work of the Toolbox Project, and specifically, from responses to the Toolbox instrument, a set of 34 prompts designed to draw out the views of scientists on some of the philosophical dimensions of their work. Importantly, the development of this instrument was a collaborative effort, with both philosophers and scientists contributing, and involved a careful review of the philosophical literature on non-epistemic values in science. The Toolbox Project continues to be a humanistic project that aims to deploy philosophical concepts and methods to facilitate improvement in scientific process, and so our *collaboration* works as a case study of how one might bridge the culture gap. Second, the data emerge out of efforts by interdisciplinary scientists and researchers to understand the role that values do and should play in their research. These are matters of central concern to the humanities more generally and philosophy more specifically, and so the *content* of our article represents a bridge between the humanities and the sciences. These data do not reveal many interesting patterns in attitudes toward specific value issues at the level of the academic branch, but they do support the conclusion that we will not find common perspectives toward values that cluster according to academic branch. Our work is exploratory, though, and so further work is called for both to buttress these results and pursue our research question at the level of academic disciplines.

What our data doesn't illuminate are relationships among assumptions and commitments of humanists and those of scientists, relationships that might help us understand the culture gap. We have argued that there are a number of important contributions that humanists can make to scientific collaborations that increase the intellectual merit of scientific projects. Among them are contributions that concern the roles that values play in constraining scientific deliberation and decision. Given the extensive history of humanists reflecting on the descriptive and normative roles of values in science (e.g. Douglas, 2000; Rudner, 1953), along with their outsider (within) status, humanists could and should be a bigger part of collaborative interdisciplinary science.

Funding

M. O'Rourke's work on this project was supported by the USDA National Institute of Food and Agriculture [Hatch project MICL02261]. S.E. Vasko's work on this project was made possible by AgBioResearch at Michigan State University. C. Gonnerman's work on this project was supported by a USI Liberal Arts Research Award.

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Citation information

Cite this article as: Human values and the value of humanities in interdisciplinary research, Brian Robinson,

Stephanie E. Vasko, Chad Gonnerman, Markus Christen & Michael O'Rourke, *Cogent Arts & Humanities* (2016), 3: 1123080.

Notes

1. We agree with Krauss (2009) that the gap remains large and largely unbridged. See also the Discussion section for reflection on the number of humanists and artists in our data-set.
2. While we follow Snow in considering in analyzing cultural distinctions between the sciences and arts and humanities, we do not share a commitment to there being precisely two cultures. It is not obvious that, for instance, all the sciences are unified in one scientific culture. The method of analysis presented below in fact allows for such differences. Therefore, we focus on the problem of the culture gap, regardless of how many cultures there are, and ways in which the gap or gaps can be bridged.
3. To clarify the terminology, "discipline" refers to defined research fields with a shared reference frame and methodology and some degree of institutionalization (e.g. journals, professional associations, and institutes). By "branches" we refer to groups of disciplines like "life sciences," "medicine and health sciences," or "social and behavioral sciences."
4. While the philosophical literature we have canvassed is largely about the role that *non-epistemic* values may play in the sciences, the Toolbox prompts use "values" without any modifier. In large part, this is because the

main function of the prompts is to stimulate thought and discussion among workshop participants, leaving it open to them to discover or develop their own ways of thinking about the term. One consequence of this decision is that the match between the Toolbox prompts and the corresponding philosophical theses is often imperfect. For example, disagreement with the first prompt is consistent with Longino's position on scientific objectivity; however, it is also consistent with the view that objectivity requires adhering to epistemic values like predictive power but complete neutrality with respect to values of any other sort, a view that is not congenial toward a scientific role for non-epistemic values. We note this mismatch between the prompts and associated theses mainly to caution the reader against drawing overly strong conclusions about where Toolbox respondents tend to stand on the more specific philosophical theses.

5. The Digital Commons Three-Tiered Taxonomy of Academic Disciplines is a regularly updated taxonomy of disciplines that aims to be as comprehensive as reasonably possible by being based on multiple sources, including the Taxonomy of Research Doctoral Programs from the National Academies, the Classification of Instructional Programs, 2010 edition, from the National Center for Educational Statistics, and The University of California's list of departments and programs. It has over 1,000 categories. The first tier divides disciplines very generally into 10 larger groups, which we refer to as "academic branches." The second tier is that of disciplines (such as Philosophy or Chemistry), and the third tier divides among sub-disciplines.
6. For this, we used the participant responses independent of their academic branch. However, all participants who responded "I don't know" or "N/A" to more than one prompt were excluded to avoid a too strong bias when calculating the distances. This resulted in excluding 11 participants, for a total of 324.
7. Superparamagnetic agent mapping employs self-organizing agents governed by the dynamics of a clustering algorithm inspired by spin physics. Each participant can be imagined as a particle with a certain spin, where the calculated distances were interpreted as the spin coupling of the particles. The algorithm then transforms this coupling into a movement on the plane, i.e. particles with correlated spins (=similar answers) become more attracted to each other. Thus, superparamagnetic agent mapping typically produces clumping, where several particles clump together (connoting similarity) while collectively repelling a different cluster (connoting collective difference between the two clusters). It has been shown that this method is superior to standard methods for dimensionality reduction, such as factor analysis, principal components analysis, and multidimensional scaling, in preserving the topology of the data space with clustered data. For a mathematical introduction into this type of clustering, see Ott, Eggel, and Christen (2014) and Ott, Kern, Steeb, and Stoop (2005).
8. Recall that participants could respond to the prompts within the Likert scale or with "N/A" or "I don't know." Those participants not responding in the Likert scale were not included in Figure 1. They were, however, included in determining the percentages, i.e. the number of participants of each branch answering each point on the Likert scale were divided by the total number of participants for that branch, including those responding "N/A" or "I don't know."
9. The advantage of the Kruskal-Wallis H test over the more standard one-way ANOVA is that the Kruskal-Wallis test does not assume that the data were normally distributed, as ANOVA does. Since our data were not normally distributed, the Kruskal-Wallis is the preferred method for analyzing variance.
10. Given the variety of participant responses shown in Figure 1, these findings give us some tentative reason to think that though there is considerable variance in researchers' views on whether objectivity implies an absence of a researcher's values (Values 1) and whether it is advocacy to allow values to influence scientific research (Values 5), this difference is not based on the branch of academia to which the researcher belongs. Interpreting null results (i.e. results that do not reject the null hypothesis) can be tricky. Generally, such results do not entail that the null hypothesis is true. In this case, it remains possible that a disciplinary difference on one or all of these issues can be found by other experimental means or by simply having more participants.
11. When testing multiple null hypotheses, the likelihood of a false positive (the family-wise error rate) increases exponentially based on the number of null hypotheses being tested. In this case, 12 MWW tests were run, which results in a family-wise error rate of approximately 0.46. This means that if each of the 12 tests was evaluated for significance at the level of $p < 0.05$, then (without correction) there would be a 46% chance that at least one result reported would be a false positive. To control for family-wise error rate, we use the Holm-Bonferroni method, which lowers the p -value necessary for an individual MWW test to count as significant, so that overall the likelihood of a false positive is the standard 5%.
12. As a reminder, our superparamagnetic agent mapping technique analyzed participant responses independent of their academic branch, and therefore we were able to include participants from each of the eight academic branches. For the algorithm to work, however, participants who responded "I don't know" or "N/A" to more than one prompt were excluded since too much data would be missing to accurately plot them on the map based on which other participants had similar responses. This resulted in excluding 11 participants, for a total of 324 displayed in the superparamagnetic agent map.
13. The clustering algorithm can also be forced to look for a set number of clusters. Since we had eight branches, we forced the algorithm to seek exactly eight clusters. The clusters that emerge, however, also do not correspond to the academic branches.
14. Although we focus here on the value of humanities for the sciences, it should be noted that we emphasize elsewhere (e.g. O'Rourke & Crowley, 2013) that the sciences and humanities stand in a feedback loop with one another. Each stands to gain from mutual interaction, and gain in ways that do not reduce one to support staff for the other. We take it that experimental philosophy provides a nice illustration of this.

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Appendix 1

Table 1A. Summary of one-way Kruskal–Wallis analysis of variance tests by prompt

	<i>H</i>	<i>p</i>	<i>df</i>
Values 1	4.22	0.65	6
Values 2	17.81	0.007	6
Values 3	18.96	0.004	6
Values 4	10.57	0.10	6
Values 5	6.81	0.34	6

Table 2A. Summary of Wilcoxon–Mann–Whitney test for the prompts Values 2 and 3, comparing Life Sciences (LS), Engineering (Eng), Physical Science and Mathematics (PSM), and Social and Behavioral Sciences (SBS)

		<i>W</i>	<i>p</i>
Values 2	LS–Eng	2446	0.48
	PSM–Eng	1113.5	0.66
	SBS–Eng	1132.5	0.21
	PSM–LS	4008	0.10
	SBS–LS	4167.5	0.40
	SBS–PSM	2432.5	0.03
Values 3	LS–Eng	2095.5	0.89
	PSM–Eng	1190	0.80
	SBS–Eng	1210	0.03
	PSM–LS	4474.5	0.79
	SBS–LS *	4639	0.002
	SBS–PSM	2586.5	0.006



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